Title

"A DOWN-THE-HOLE HAMMER"

Technical Field of the Invention

The present invention relates to "down-the-hole" hammers or fluid-operated percussion drill tools operated by a supply of compressed air.

Background to the Invention

Some designs of conventional down-the-hole hammers and fluid-operated percussion drill tools comprise an external cylinder or outer wear sleeve, within which is mounted an inner cylinder which in turn engages with a backhead assembly. A sliding reciprocating piston co-operates with the inner cylinder and backhead assembly, which when air pressure is supplied through the backhead assembly, acts with a percussive effect on a drill bit retained within a chuck on the outer wear sleeve.

In down-the-hole hammers the energy created is in part dependent on the cross sectional area of the reciprocating piston. This is because the force is determined by the formula P x A (where P = air pressure and A = cross sectional area of the piston). In most modern down-the-hole hammers the piston is a sliding valve, which reciprocates between a strike position on a bit and a top of stroke position. The length and timing of the stroke is determined by the supply and exhaust of air to a lift chamber and top pressure chamber.

In known conventional arrangements, the inner cylinder is effectively suspended within the outer wear sleeve by means of a compressible retaining ring, such as a circlip, which has to be slid up the inner cylinder so as to seat against a shoulder or lip at one end thereof, being compressed when the inner cylinder is dropped down within the outer wear sleeve, and then expanding outwardly into a groove or shoulder formed on the inner diameter of the outer wear sleeve with a snap action. When in this position, the

circlip seats within the groove and abuts against the lip of the inner cylinder, by which the inner cylinder is suspended within the outer wear sleeve.

EP1004744A, of the same applicant, discloses a segmented ring mounting for retaining the inner cylinder within the outer wear sleeve in a fluid-operated percussion drill tool, such as a down-the-hole hammer.

The retaining ring seats the smaller diameter inner cylinder within the larger diameter outer wear sleeve. The outer wear sleeve is formed with a groove cut on its inside diameter, or a shoulder for seating the retaining ring against a lip of the inner cylinder. The ring is capable of radial compression and expansion so as to expand radially into the seating groove or shoulder for retaining the components one within the other in use. The retaining ring comprises at least three segments, which when touching end to end form a complete circle, and an expansible O-ring, for holding the segments together but allowing the segments to expand radially and move apart by sufficient amount so as to seat the segments in the groove or against the shoulder.

The inner cylinder of EP1004744A is integral to the porting of the hammer. In the system the piston runs on the inner diameter of the inner cylinder and also on the inner diameter of the outer wear sleeve. It is essential that the fit between the outer diameter of the inner cylinder and the bore of the outer wear sleeve be a tight/close fit to ensure optimum alignment of the two bores. This means that the clearance and hence the efficiency of the hammer is optimised because the operation of the hammer relies on a partial seal between the piston and the top and bottom chambers, i.e. the tighter the clearance the greater the energy (within reason). In the seating ring system of EP1004744A effective operation relies on a difference in wear sleeve bore diameter above and below the seating ring groove. This means the usable diameter for the piston, and thus the energy, is reduced. This is because the inner diameter of the wear sleeve above the seating ring has to be larger than below to ensure that the seating ring is located in position. This results in an effective reduction in the cross-sectional diameter of the piston, which reduces the force on the piston.

Other manufacturers have in the past made the inner cylinder as part of a threaded component which screws into the outer wear sleeve. The disadvantage of this is that the hammer wears externally and in many cases it is rebuilt by replacing all external components. This would obviously be extremely expensive in the above scenario. There is also the issue of the clearance which would be necessary, between the external diameter of the inner cylinder portion and the bore of the wear sleeve, to allow the component to screw into the wear sleeve. As will be explained below the clearance needs to be minimised to optimise the concentricity of the inner cylinder bore and the wear sleeve bore.

In other known prior art percussion hammers the inner cylinder is mounted within the outer wear sleeve by means of a compressible retaining ring, such as a circlip, which is expanded outwardly to seat into the groove or shoulder formed on the inner diameter of the outer wear sleeve.

The outer wear sleeve of down-the-hole hammers is subject to very strong abrasive forces when in use causing significant wear of, and removal of metal from, the outer sleeve. This weakens the outer wear sleeve to the point where it has to be replaced. In the prior art hammers described the provision of circumferential seating grooves for circlips, seating rings and the like, in the inner face of the wear sleeve reduce the wear thickness of the outer sleeve. This means that the outer wear sleeve has to be replaced more quickly than would be the case if the wear sleeve contained no more grooves.

In other prior art down-the-hole hammers (e.g. those having a seating ring) the inner cylinder is located on a shoulder provided by a groove in the wear sleeve. It is then locked in position by the application of torque at the backhead, which locks down on a compression ring or the like. The result is that there is a significant locking force which acts between the shoulder and the threads of the wear sleeve. The possibility that this force could cause distortion on the wear sleeve will increase as the external wear on the wear sleeve outer diameter increases.

Another type of locking system relies on a collet type system (e.g. WO9967065 Azuko). This system applies not only a force down an shoulder on the wear sleeve but also an outward force on the wear sleeve. Again the effect of these forces increases as the wear sleeve wears.

In summary, the disadvantages of the prior art systems are as follows.

Where a seating ring is used this results in:

- a reduction of the available piston cross-section due to shoulder requirements for the seating ring;
- a reduction of wear sleeve cross-section due to the requirement to provide a seating ring groove;
- high locking forces required on the seating ring shoulder of the wear sleeve.

Where a compressible/expandable circlip is used this results in:

- a reduction of the wear sleeve cross-section due to the requirement to provide a seating ring groove;
- high locking forces required on the seating ring shoulder of the wear sleeve.

Where an integral inner cylinder and threaded component is used, this results in:

- a requirement for clearance between the inner cylinder and the wear sleeve resulting in concentricity problems;
- it is expensive to rebuild.

Object of the Invention

It is an object of the invention to provide a down-the-hole hammer, or other fluid operated percussion drill tool, having means for rigidly mounting the inner cylinder in

the outer wear sleeve while still maximising the bore of the wear sleeve. It is also an object of the invention to obviate the need for a seating groove in the outer wear sleeve, and to minimise areas of weakness in the outer wear sleeve.

Summary of the Invention

The invention provides a fluid-operated percussion drill tool, in particular a down-the-hole hammer, comprising an external cylindrical outer wear sleeve, an inner cylinder mounted co-axially within the outer wear sleeve, a sliding piston mounted for reciprocating movement within the inner cylinder and the outer wear sleeve, to strike a hammer bit mounted at the lower end of the outer wear sleeve, characterised in that the inner cylinder is formed with an inwardly-directed abutment which in the assembled tool is clamped between a complementary engagement means and a locking means such that the inner cylinder is rigidly mounted and held in the drill tool assembly relative to the outer wear sleeve.

Preferably, an elongate cylindrical air distributor is positioned within the hammer assembly, and a lower end of the air distributor is positioned substantially concentrically within the upper end of the inner cylinder and an abutment on the air distributor engages the underside of a complementary abutment on the inner cylinder. Preferably, the top end of the outer wear sleeve is screw-threadably engaged with the lower end of an annular air distributor mount, and the top end of the inner cylinder abuts the lower end of the distributor mount such that the inner cylinder is rigidly mounted in the drill assembly relative to the outer wear sleeve when a top locking member is threadably mounted onto the air distributor.

The air distributor is threadably engaged at its upper end with a top locking member which abuts the top of the air distributor mount.

Thus, in the drill assembly of the invention, the inner cylinder is rigidly held relative to the outer wear sleeve.

There is no requirement for a mounting groove for the inner cylinder within the outer wear sleeve, which can be a weak point in the assembly.

Brief Description of the Drawings

Embodiments of a down-the-hole hammer in accordance with the invention will now be described with reference to the accompanying drawings, wherein:

Figure 1 is a sectional side elevation of a first embodiment of a down-the-hole hammer of the invention, showing the piston in the strike position;

Figure 2 is a sectional side elevation of the down-the-hole hammer ofFigure 1, showing the piston in the top of stroke position;

Figure 3 is a sectional side elevation of the top part of the hammer of Figure 1 to a larger scale;

Figure 4 is a sectional side elevation, to an enlarged scale, showing a detail of Figure 3;

Figure 5 is a cross-sectional plan view of the down-the-hole hammer of Figure 1, on the line C-C of Figure 3;

Figure 6 is a cross-sectional plan view of the down-the-hole hammer of Figure 1, on the line B-B of Figure 3;

Figure 7 is a cross-sectional plan view of the down-the-hole hammer of Figure 1, on the line D-D of Figure 3;

Figure 8 is a cross-sectional plan view of the down-the-hole hammer of Figure 1, on the line E-E of Figure 3;

Figure 9 is a cross-sectional plan view of the down-the-hole hammer of Figure 1, on the line F-F of Figure 3;

Figure 10 is a sectional side elevation of a second embodiment of a down-the hole hammer of the invention, showing the piston in the strike position; and

Figure 11 is sectional side elevation of the top part of the hammer of Figure 10 to a larger scale.

Detailed Description of the Drawings

Referring to Figures 1 to 4 of the drawings a first embodiment of a down-the-hole hammer of the invention comprises an external cylindrical outer wear sleeve 10. An inner cylinder 9 is mounted co-axially within the outer wear sleeve 10. A sliding piston 11 is mounted for reciprocating movement within the inner cylinder 9 and the outer wear sleeve 10, to strike a hammer bit 36 mounted for sliding movement in a chuck 41 located at the forward end of the outer wear sleeve 10, in well known manner.

Referring now to Fig. 3, at the back end of the hammer, a top locking member 1 is screw-threadably mounted on an annular air distributor 3. Air distributor 3 is fitted concentrically through inner cylinder 9 and a distributor mount 2 and when assembled an outwardly-directed annular flange 38 on the lower end of air distributor 3 abuts the underside of an inwardly-directed annular shoulder 15 in inner cylinder 9. The top end 14 of inner cylinder 9, above the shoulder 15, in turn abuts the lower end of the distributor mount 2. The distributor mount 2 is substantially cylindrical and open at both ends. It has an upper part 2a having an outer diameter which is the same as the outer diameter of the outer wear sleeve 10, such that when the mount 2 is engaged with the wear sleeve (as described below) the outer cylindrical wall of the mount 2 is flush with the outer wall of the wear sleeve 10. The mount 2 has a lower part 2b of reduced diameter which fits within the top end of the wear sleeve 10, and is screw-threadably engaged with the inner wall of the wear sleeve 10, by means of screw threads 39 (see also Fig. 8). The transition between the upper and lower parts of the distributor mount 2

is defined by a downwardly facing annular shoulder 23, against which the top annular rim of the wear sleeve 10 abuts, and is locked in place when the mount 2 is fully engaged with the wear sleeve 10. The bottom of the top locking member 1 has a flat annular rim 12 which engages a complementary flat shoulder 13 on the top end of the distributor mount 2. The inner cylinder 9 is thus effectively locked between a shoulder 13 (between top locking member 1 and mount 2) and shoulder 15 (between air distributor 3 and inner cylinder 9). Shoulder 15 may be tapered if required.

Stated differently, the inner cylinder 9, at its upper end, has an inwardly extending annular shoulder or flange 14 which is rigidly held between the shoulder 15 and the lower end of the distributor mount 2, when the distributor mount 2 has been screwed into position in the top end of the wear sleeve 10, and the top locking member 1 has been screwed on to the air distributor. When the top-locking member 1 is screwed down, by screw-threadably engaging it with the top of the air-distributor 3, this acts to pull the air-distributor 3 upwardly against the shoulder 15, and in turn pulls the inner cylinder 9 upwardly against the shoulder 14. The whole assembly then locks down on shoulder 13.

When screw engaging top locking member 1 to air distributor 3, air distributor 3 is prevented from turning by means of dowels 8 positioned between mount 2 and air distributor 3. An annular circlip 7 (see Figs. 3 and 4) is positioned in a chamber 24 formed between locking member 1 and mount 2 and a groove 25 machined on air distributor 3. The circlip 7 serves to retain air distributor 3 loosely in position when assembling the hammer.

Instead of the dowels 8, other means (not shown) may be provided to prevent the air distributor 3 from turning as the top locking member 1 is being screwed in place in assembling the hammer. For example, the air distributor 1 may be provided with external flats (flat surface) which mate with complementary flats milled internally in the distributor mount 2.

To ensure maximum alignment between the inner cylinder 9 and the wear sleeve 10 the fit must be as close to size for size as possible. Due to tolerance restrictions this

means that the fit could be a very close sliding fit, a size for size fit, or a slight interference fit. The efficiency of the hammer is partly dependent upon the clearance between the piston 11 and the wear sleeve 10, because the sliding contact between the piston 11 and the inner diameter of the wear sleeve 10 acts as a pneumatic seal. The clearance between these parts is of the order of 0.1 mm. It will be appreciated that the piston 11 is running in the bore of the wear sleeve 10 at the lower end of its stroke (see Fig. 1) and runs in the bore of the inner cylinder 9 at the top of the stroke (see Fig. 2). Again the clearance is of the order of 0.1 mm. It is also important to ensure that the bore of the inner cylinder 9 is concentric with the bore of the outer wear sleeve 10, and that there is no sideways (i.e. radial) movement. This is achieved by having the inner cylinder 9 as a very snug, or interference, fit within the bore of the outer sleeve 10.

The tolerance on the bore of the outer wear sleeve 10 relative to the piston 11 is about 20 microns and a tolerance of about 10 microns in the outer diameter of the inner cylinder 9, relative to the outer diameter of the piston 11. The clearance between these parts should be in the range of 0.11 mm and 0.14 mm. If the clearance is greater than about 0.14 mm there is a loss of efficiency of the hammer because compressed air bypasses the piston.

As mentioned above, the mount 2 is screw-threadably engaged with the top of wear sleeve 10 by means of screw threads 39 (see Figs. 3 and 8) which are cut into the inner face of the wear sleeve 10. The axial depth of cut of the screw thread 39 is kept to a minimum to minimise the stress on the wear sleeve. When considering the axial depth of screw thread 39 it is important to note that as the diameter of the hammer increases (hammer models are generally denoted by the nominal size which they are designed to drill e.g. 3", 4", 5", 6", 8" etc..) the minimum thread depth would increase. In the case of 3" and 4" hammers the minimum depth could be in the range of 1.0 to 1.4 mm. On the larger sizes, e.g. 8", this minimum depth could be in the range of 1.6mm to 2.0mm.

In a preferred method of assembly of the hammer, the bottom end of the hammer is assembled first. The hammer is then placed upright. The piston 11 is placed into the wear sleeve 10. The air distributor 3 is placed into the wear sleeve 10 such that the

probe 6 is sitting within piston 11. The inner cylinder 9 is pushed into the wear sleeve 10. The distributor mount 2 is screwed into the wear sleeve 10. The assembly is then tipped on end so that distributor 3 falls down through mount 2 Where the dowels 8 are used these are assembled, and an O-ring is placed on distributor 3. The check valve 4 and a spring are put in position. The top locking member 1 is then screwed onto the end of distributor 3.

There are other ways of assembling hammer but the above method has been found to be convenient.

For example, in an alternative method of assembly, the air distributor 3 is inserted into inner cylinder 9 (the probe 6 has already been inserted in air distributor 3). The distributor mount 2 is placed over air distributor 3. Dowels 8 are inserted in position in grooves 26 in distributor mount 2, and complementary grooves 27 in air distributor 3 (see Fig. 6). Once the dowels are in place the air distributor 3 cannot rotate. The circlip 7 is assembled in groove 25 on air distributor 3 (see Figs. 3 and 4). If the assembly at this stage is stood on inner cylinder 9, then air distributor 3 can fall as far as circlip 7 allows it. In this position circlip 7 is in groove 24 (in distributor mount 2) and cannot come out. Thus the assembly can be inserted into wear sleeve 10 by applying force until the distributor mount 2 is in position to screw into wear sleeve 10. On screwing the distributor mount 2 into the wear sleeve 10, the inner cylinder 9 will be gradually pushed into position. When the distributor mount 2 abuts wear sleeve 10 at shoulder 23, the top locking member 1 is screwed to air distributor 3 by screw threads 42 (see Fig. 7). When the locking member 1 is locked on shoulder 13, the inner cylinder 9 is held securely in position, and circlip 7 has pulled up in space 24 to a top position. Thus, the function of the circlip 7 is to prevent the air distributor 3 from falling down into the hammer assembly before the locking member 1 is in place. After the locking member 1 has been screwed into position the air distributor 3 is firmly held in position and the circlip 7 becomes redundant.

The operation of the hammer is as follows. Referring to Fig. 3, compressed air is supplied through top locking member 1 and forces check valve 4 open by pushing

down on a compression spring 5. The compressed air is then supplied through an annular chamber 16 formed between air distributor 3 and probe 6 (see Figs. 3 and 7). The air then passes through ports 17 in air distributor 3 and into four chambers 18 (see Figs. 3 and 8), which are segmental in plan, and are formed between distributor mount 2 and air distributor 3. From there the compressed air passes down through ports 19 in inner cylinder 9 and into the segmentally-shaped chambers 20 (see Fig. 9) between the inner cylinder 9 and the wear sleeve 10. From here the air is supplied through ports 21 in the inner cylinder 9.

When the piston 11 is in the strike position (Fig 1), air is supplied from the ports 21 into the chamber 28 between the piston 11 and the wear sleeve 10. From here it is supplied through the channels 29 in the piston 11 to undercut 30 and into lift chamber 31.

At the back end of the piston, in a top chamber 32, air is free to exhaust through piston bore 33 and bit bores 34 and 35 to atmosphere. As a result a pressure differential exists between the lift chamber 31 and the top chamber 32 and the piston lifts to the top of stroke position (Fig. 2).

In this position air is cut-off from entering chamber 31, and air can exhaust from chamber 31 through bit bores 34 and 35 to atmosphere. Pressurised air is supplied from ports 21 to a chamber 38 between piston 11 and inner cylinder 9. From here it is supplied though channels 37 in inner cylinder 9 to top chamber 32 which is prevented from exhausting by probe 6 which is in piston bore 33. As there is now a pressure differential between chambers 31 and 32 the piston is driven down to strike the bit 36 and the cycle repeats itself.

A second embodiment of the down-the hole hammer is now described with reference to Figures 10 and 11 of the drawings. This embodiment is substantially similar in construction and operation to the first embodiment of Figures 1 to 9, and like reference numerals denote like parts.

It has been found in use of the first embodiment that there is a risk that the distributor mount 2 may crack if excessive force is applied to it from the top locking member 1 due to torqueing up of the assembly in operation. This risk may be avoided by providing a stop for the downward movement of the top locking member 1 on the top end of the air distributor 3.

As shown in Figure 11, the stop is provided by means of an annular flat shoulder 50 on the inner surface of the top locking member 1, which abuts the top flat annular end 51 of the air-distributor 3, when the inner cylinder 9 is locked in position. In practice the locking is achieved, by arranging the length tolerances to be such that, as the inner cylinder 9, is locked, there is a small gap between the end 51 of the air-distributor 3 and shoulder 50. As the hammer tightens due to applied torque in operation, this gap is closed. Alternatively, a compression ring (not shown) may be positioned between the end 51 and the shoulder 50 which absorbs forces as the assembly tightens. This also makes up for variation in lengths due to tolerances.

The length tolerances referred to are the length of distributor 3 from end 51 to shoulder 15; the length of inner cylinder 9 from shoulder 15 to the top end 14 of the inner cylinder; the overall length of mount 2, and the length from shoulder 12 on top locking member 1 to shoulder 50. These lengths are chosen to achieve a small gap between the shoulder 50 and the flat end 51. As explained about, this gap closes in operation of the hammer. If it is not desired to be restricted to tight length tolerances then a compression ring may be inserted between shoulder 50 and the flat end 51 as explained above.

In this embodiment, the air distributor 3 is all in one piece which improves the strength of the assembly.

As shown in Figure 11, in this embodiment the annular circlip 7 shown in Figures 3 and 4, is replaced by a rubber O-ring 53 positioned between the lower inner end of the locking member 1 and the air-distributor 3.

From the foregoing, it will be apparent that numerous modifications and variations can be effected without departing from the true spirit and scope of the novel concept of the present invention. It will be appreciated that the present disclosure is intended to set forth the exemplifications of the invention which are not intended to limit the invention to the specific embodiments illustrated. The disclosure is intended to cover by the appended claims all such modifications as fall within the scope of the claims.

Where technical features mentioned in any claim are followed by reference signs, these reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, such reference signs do not have any limiting effect on the scope of each element identified by way of example by such reference signs.

The words “comprises/comprising” and the words “having/including” when used herein with reference to the present invention are used to specify the presence of stated features, integers, steps or components but does not preclude the presence or addition of one or more other features, integers, steps, components and groups thereof.